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| Ownership matrix | **RPP-27195** |

## 1.0 PURPOSE AND SCOPE
(5.1.1)

This standard provides the design and installation requirements for electrical raceways and flexible cords and cables for Tank Operations Contractor facilities. The general requirements are provided in the National Electrical Code (NEC), and this standard clarifies NEC requirements and provides supplementary requirements applicable to WRPS facilities. In cases of conflict between this standard and the NEC, this standard is the prevailing requirement.

This standard includes a consistent approach to engineering evaluation of: ambient temperature, the long-term effects of operating temperature on life expectancy of various cord or cable insulating materials, and the suitability of a cord or cable for a specific installation. This standard shall not apply to designs completed before the date shown in the header.

This standard shall not apply to any signaling, control, or communications circuit powered exclusively from a single UL listed Class II power supply.

## 2.0 IMPLEMENTATION

This standard is effective on the date shown in the header. It does not apply to any existing equipment in service, nor to identical replacements of utilization equipment. It applies to new facilities and to all modifications of, and additions to, existing facilities.

## 3.0 STANDARD
(5.1.2)

Except as required by this document, electrical raceways, flexible cords, and cables shall comply with the NEC.

### 3.1 General
(5.1.2)

The sizes of conduits, etc. shall be indicated on the as-built drawings (e.g., within wire-run and conduit/raceway schedules and/or electrical plans).

An equipment grounding conductor wire shall be installed in every raceway that contains:

- A power feeder or branch circuit, or
- Control power exceeding 50V nominal to a device having no other grounding conductor wire.

The design shall provide conduit sealing fittings with approved sealant at the following locations:

- Where conduits pass between areas where air pressure differential must be maintained.[1]

[1]Occupancies where air pressure differential is used to assure containment or confinement.

- Where conduits pass between areas where vapor separation must be maintained (e.g., flammable gas environment on one side of the seal).

Electrical Metallic Tubing (EMT) shall not be embedded in concrete or buried in earth.

Polyvinyl chloride (PVC) coated rigid metal conduit is the preferred material installed inside Tank Farm Areas.

PVC conduit shall not be used inside Tank Farm Areas.

## 3.2 Underground Raceway Systems Located Within the Tank Farm Fences

(5.1.3)

Underground Rigid Metallic Conduit (RMC) up to and including four-inch diameter shall be installed at a minimum depth of 12 inches to the top of conduit for traffic areas or a minimum depth of 6 inches in non-traffic areas.[2]

Design drawings shall identify physical routing and usage parameters for the underground raceway systems.

The minimum size of underground RMC within the tank farm fenced areas shall be one-inch in diameter.

## 3.3 Flexible Cords and Cables

(5.1.2, 5.1.3)

Portable or skid mounted equipment shall be wired using either fixed wiring methods, or shall comply with NEC Article 400, "Flexible Cords and Cables." Fixed wiring shall be installed wherever it is both operationally practicable and it can be installed in compliance with sections of this standard that cover fixed wiring methods. Some restrictions may apply to fixed wiring methods due to safety considerations.

Where fixed wiring is not operationally practicable or cannot be installed without incurring safety hazards, the installation shall conform to NEC Article 400, "Flexible Cords and Cables."

Wiring method shall not be based on NEC Article 590, "Temporary Installations," unless fully conforming to the activities identified in NEC Article 590.3, "Time Constraints," and are genuinely activity-based as follows:

- The temporary installation serves no purpose other than the activity that is used to define the time constraint.
- The activity has a clearly identified and fixed scope, and a fixed completion date.
- The activity inherently creates significant changes in the physical environment or the physical arrangement of the temporary installation.
- The temporary installation does not exist prior to start of the activity.

[2]This is an exception to NEC burial depths. See Letter # 9503714, "Request for Approval – Conduit Burial Depths in Tank Farm Facilities" and Letter # 9552916, "Conduit Burial Depths in Tank Farm Facilities"

- The temporary installation is removed immediately upon completion of the activity.

NEC Article 590 temporary installations shall be limited to activities where a lack of configuration control is necessitated by the practical limitations of an activity of Construction, Remodeling, Maintenance, Repair, Demolition, Emergency, Tests, Experiments, Developmental Work, or Holiday Lighting, as identified in NEC Article 590.3.

Infrared lamp industrial heating equipment wired with flexible cords or cables shall comply with NEC Article 422.48, "Infrared Lamp Industrial Heating Appliances."

Industrial appliances that are wired with flexible cord or cable shall comply with applicable sections of NEC Article 422, "Appliances".

All industrial appliances that are wired with flexible cords or cables shall conform to NEC definition of 'Appliance', or shall comply with NEC Article 400.7, "Uses Permitted."

Only OSHA NRTL listed cords and cables shall be used, of the types appearing in NEC table 400.5A.

Extra-hard usage flexible cord or cable listed in NEC table 400.4 shall be used in outdoor locations.

## 3.4 Raceway Attached to Buildings or Immobile Outdoor Structures

(5.1.2, 5.1.3)

Above ground raceway shall be supported by a building or other immobile structure.

The following shall be considered where conduit is installed outdoors, at or above grade:

1. NEC Article 300.7, Raceways Exposed to Different Temperatures, requires expansion fittings "where necessary to compensate for thermal expansion".

2. For steel conduit, the expansion rate is $6.45 \times 10^{-6}$ in/in per °F. The temperature span from TFC-ENG-STD-02, Table 1, "Design Basis Air Temperatures," is 140°F. Multiplying $6.45 \times 10^{-6}$ x 140°F x 1,200 inches, yields 1.1 inches per 100 feet, in the shade. In the sun, 180°F yields 1.6 inches per 100 feet.

3. Evaluation of thermal expansion and conduit supports may be done using AutoPIPE.

Expansion fittings shall be included where equipment or equipment supports would otherwise be subject to damage.

Where expansion fittings are included, conduit supports shall be designed to permit movement of the conduit toward and away from the expansion fitting, and to prevent expansion or contraction forces on the equipment to which the conduit connects.

Where more than one expansion fitting is included between conduit terminations, each span of conduit that attached to an expansion fitting at both ends of the span shall be immobilized at mid-span.

Expansion fittings shall be adjusted for ambient temperature during installation so that summer and winter temperature extremes will not exceed motion limits of the expansion joint.

Appropriate flexible bonding jumpers shall be installed around expansion joints to maintain grounding paths.

## 3.5 Buried Raceway and Direct Buried Cable

(5.1.2, 5.1.3)

The following shall be considered before conduit or cable is installed below grade in contaminated soil or protected areas:

1. Disturbance of contaminated soil, without a soil remediation plan, may result in increased risk of exposure to contamination, and to the spread of contamination above and below the excavation, as well as in every other direction.

2. To avoid hazards of excavating in contaminated soil, protected environments, and documented cultural resources, mining power cable, NEC Type W, and Class 2 instrumentation and control wiring is less expensive than burial, and is very often installed at Hanford site facilities to serve equipment described in NEC Article 400, "Flexible Cords and Cables", 400.10, "Uses Permitted," (6) "Connection of utilization equipment to facilitate frequent interchange."

3. "Frequent interchange" has been well established at Hanford site facilities, to include any possibility of relocation before the host facility is decommissioned. The following examples specifically include such immobile and permanent structures as water wells installed 250 feet deep, where served by electrical equipment that is mounted on a freestanding rack anchored to a block of concrete laying on grade and movable by forklift, as well as other equipment and structures subject to eventual relocation. This method of wiring without excavation is shown in the following drawings:

    - H-1-91451, 100H Electrical Site Plan
    - H-1-91103, 200W Standard Road Crossing Civil Details.

## 3.6 Overhead Wire and Cable

(5.1.2, 5.1.3, 5.1.4)

Overhead installations shall provide clearances required by ANSI/IEEE C2, *National Electrical Safety Code*, and DOE-0359, *Hanford Site Electrical Safety Program*.

## 3.7 Flexible Cord and Cable Protection

(5.1.2, 5.1.3, 5.1.5)

Flexible cord or cable laid on-grade shall be protected from damage using vehicle route boundary markers and roped-off pedestrian areas. Where more than ten feet of any cable or flexible cord is enclosed in cable protectors, its ampacity shall be reduced as required in Section 3.8 and 3.9.

Cable protection design and installation requirements shall be documented on electrical drawings.

Cable inspection and testing requirements shall be documented on drawings, for outdoor cable and for any cable exposed to thermal or radiation aging hazards. These requirements shall cover:

- Testing of safety grounding conductor continuity, and
- Inspection, testing and recording of insulation hardness and fatigue.

Cable inspection and testing requirements shall include:

- Five years maximum interval
- Immediately after being subjected to likely damage
- After being physically relocated, before being re-energized
- After conducting an electrical fault.

Where cable protectors are used, they shall be installed per the manufacturer's instructions.

Cables entering or exiting cable protectors shall use transition devices as provided and/or recommended by the manufacturer.

Installation of cable protectors within Tank Farm fences shall be documented on the Approved Route Map Drawings required by TFC-ENG-FACSUP-C-10.

## 3.8 Flexible Cord and Cable Ampacity De-rating
(5.1.2, 5.1.3)

Flexible cords and cables shall be de-rated to account for reduced heat-transfer where they are installed in protective covering exceeding the lengths permitted by NEC 310.15(A)(2) where the covering can restrict air flow or expose a larger profile to solar gain.

In absence of an engineering analysis of heat transfer characteristics of the cable protection covering and the life expectancy of the cord or cable, outdoor cord or cable shall be de-rated to ambient of 113ºF plus the temperature rise above the surrounding ground temperature that is seen by the protective covering when exposed to direct summer sunlight, early afternoon. The highest outdoor temperature recorded on the Hanford site is 113°F (PNNL-15160).

In the absence of any measurements of cable protector temperatures, outdoor cord or cable shall be de-rated to an ambient temperature of 140ºF (60ºC) and cord or cable terminating devices shall be rated at minimum, 167ºF (75ºC) operating temperature. 140ºF was first measured by the author as representative of numerous measurements using infrared temperature sensor on a typical soil/gravel surface in direct sunlight, then corroborated with NEC referenced Copper Development Association, "Outdoor Temperatures for Selected U.S. and Canadian Cities and Temperatures Inside Raceways on Rooftops Exposed to Direct Sunlight" which publishes ASHRAE temperature data for cities throughout USA including Pasco/Ice Harbor at 118°F/48°C, August 5, 1961 and one earlier date, and published calculated conduit internal temperatures of 157°F to 137°F for 0" to 3-1/2" above the surface, noting that the Ice Harbor data is 5°F higher than Hanford site record, and that cable protectors are at nominal 0" above the surface.

Where more than one flexible cord or cable is installed in the same protective covering, their ampacity shall be further de-rated using NEC table 400.5(A)(3) for more than three current-carrying conductors.

## 3.9 Ampacity Calculations and Temperature Derating
(5.1.2, 5.1.3)

Engineering Calculations complying with TFC-ENG-DESIGN-C-10 shall be provided wherever Engineering Supervision is required by NEC article 310.15(C) due to temperature considerations that are not reflected in NEC ampacity tables, including:

- Wiring, Cords and Cables in Duct Banks
- Wiring, Cords and Cables in Cable Trays with Fire Retardant
- Wiring in Ceilings, Walls, or Floors with Thermal Insulation
- Wiring, Cords and Cables in Cable Protection exceeding the lengths permitted by NEC 310.15(A)(2)
- All other Wiring, Cords and Cables in locations where conditions of heat loss is not accurately represented by any NEC ampacity table
- All Flexible Cords where temperature rating of wire termination is less than temperature rating of the flexible cord and no corresponding ampacity table exists in NEC for that temperature.

Where wiring, cord, or cable is fed from equipment indoors in a controlled environment, i.e., electrical equipment room, and exceeds the lengths permitted by NEC 310.15(A)(2) before entering a higher ambient temperature, ampacity shall be the least of the two ampacities calculated for either termination, to assure that neither temperature limit is exceeded.

Temperature calculations for wiring, cords and cables shall express the maximum operating temperature of the conductor at the maximum ambient temperature when carrying the maximum NEC required load and shall show that the maximum operating temperature is less than the least of the temperature rating of the terminal device and the temperature rating of the involved wire, cord or cable.

Where an NEC table shows ampacity for appropriate conditions of heat loss, but does not show appropriate temperature limits for the involved conductor termination, i.e., NEC Table 400.5(A)(1) for flexible cords, the engineering calculation may use a square root method of apportioning ampacity to temperature rise, so as to reduce the ampacity to an acceptable temperature rise. For such apportioning, the allowable temperature rise shall be made explicit as the difference between terminal temperature rating and maximum ambient temperature, and the rated temperature rise for the ampacity listed in the table shall be made explicit as the difference between the maximum conductor temperature rating and the ambient temperature at which the conductor is rated.

## 3.10 Metal Clad and Armored Cable
(5.1.2, 5.1.3)

Types MC and AC wiring methods are NOT approved in NEC Article 400. Types MC and AC are very vulnerable to crush or impact damage.

Types MC and AC shall NOT be installed where subject to vehicular or pedestrian traffic, nor in any other location where ordinary extension cords and many other types of flexible cords and cables are better suited to withstand crush and impact.

Types MC and AC shall NOT be installed where extension cords and many other flexible cords and cables are more suited to be supported on grade with no special bedding or securing, and without removal of vegetation or natural ground covering.

Types MC and AC shall be physically secured (NEC Articles 320 and 330).

Without the extra protection of conduit, type MC or AC may be installed, where inaccessible or where exposed only to occasional accidental abrasion, scratching.

Types MC and AC shall be supported by a building or other immobile structure.

## 4.0 DEFINITIONS

Appliance. Utilization equipment, generally other than industrial, that is normally built in standardized sizes or types and is installed or connected as a unit to perform one or more functions such as clothes washing, air-conditioning, food mixing, deep frying, and so forth.

Equipment. A general term, including fittings, devices, appliances, luminaires, apparatus, machinery, and the like used as a part of, or in connection with, an electrical installation.

## 5.0 SOURCES

### 5.1 Requirements

5.1.1 DOE O 252.1A, “Technical Standards Program.”

5.1.2 NFPA-70, National Electrical Code (NEC).

5.1.3 Standard Engineering Practice.

5.1.4 TFC-ENG-FACSUP-C-10, “Control of Dome Loading and SSC Load Control.”

5.1.5 TFC-OPS-OPER-C-10, “Vehicle and Dome Load Control in Tank Farm Facilities.”

### 5.2 References

5.2.1 Letter #9503714, “Request for Approval – Conduit Burial Depths in Tank Farm Facilities.”

5.2.2 Letter #9552916, “Conduit Burial Depths in Tank Farm Facilities.”